SECTION I.—AEROLOGY.

SOLAR AND SKY RADIATION MEASURED AT WASHINGTON, D. C., DURING MAY, 1915.

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[Dated: Washington, D. C., June 10, 1915.]

In Table 1 are summarized the measurements of the intensity of direct solar radiation made by the Weather Bureau at the American University[1] during May 1915. A Marvin pyrheliometer was employed in making measurements. The sky was generally unfavorable for this work, as the occasions were rare when some clouds were not present. However, a measurement of 1.45 calories per minute per square centimeter of normal surface, obtained shortly after noon of the 27th, is the highest ever obtained at Washington in the month of May. On other days the intensities were generally below the average for May.

Sky-light polarization, measured at a point 90° from the sun and in his vertical, with the sun at zenith distance 60°, averaged 50 per cent. with a maximum of 53 per cent, which is 4 per cent below the average maximum for May.

In Table 2, column 2 gives the daily totals of solar and sky radiation received on a horizontal surface at the American University. The measurements were made with a Callendar recording pyrheliometer in the manner described in this REVIEW for March, 1915, **43**:100. Column 3 of Table 2 gives the departures of these daily totals from the daily normals published in the same number of the REVIEW, p. 108, Table 4.

TABLE 1.—*Solar radiation intensities at Washington, D. C., during May, 1915.*

[Gram-calories per minute per square centimeter of normal surface.]

Date.	Sun's zenith distance.										
	0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°	80.7°
	Air mass.										
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
1915 A. M.	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*
May 1	1.20	1.02									
2		1.22	1.07	0.96							
6		1.15	1.03	0.93	0.85	0.78	0.70	0.65	0.59	0.54	0.50
9		1.19	1.06								
10			1.04	0.83	0.64	0.59					
15				0.70							
18		1.18	1.01	0.92							
23		1.17									
24		1.21	1.12								
27	1.46	1.36	1.27	1.18	1.09	1.03	0.99				
31		1.27									
Means	(1.33)	1.20	1.09	0.92	0.86	0.80	(0.84)	(0.65)	(0.59)	(0.54)	(0.50)
P. M.											
May 4	1.33										
10	1.17	1.02	0.87	0.78	0.69	0.60	0.52				
27	1.46	1.33	1.25	1.17	1.10	1.02	0.96	0.89	0.81		
Means	(1.40)	(1.25)	(1.14)	(1.02)	(0.99)	(0.86)	(0.78)	(0.70)	(0.81)		

The "Percentage of possible sunshine," and the "Average cloudiness," given in columns 5 and 6 of Table 2, have been taken from the records of the observatory at the central office of the Weather Bureau.

The above data show more than the average cloudiness, less than the average sunshine, and solar radiation below the average intensity for the month, during May, 1915, and especially during the last two decades.

TABLE 2.—*Daily totals and departures of solar and sky radiation at Washington, D. C., during May, 1915.*

[Gram-calories per square centimeter of horizontal surface.]

Date.	Daily total.	Departure from normal.	Excess or deficiency since first of month.	Percentage of possible sunshine.	Average cloudiness.
	Gr.-cal.	*Gr.-cal.*	*Gr.-cal.*	*Per cent.*	*0–10*
May 1	458	−36	−36	46	7
2	507	8	−28	82	4
3	433	−71	−99	43	6
4	375	−134	−233	34	7
5	436	−78	−311	71	6
6	578	60	−251	98	3
7	319	−201	−452	24	10
8	388	−134	−586	14	9
9	636	112	−474	100	1
10	564	38	−436	93	3
11	520	−7	−443	93	6
12	71	−458	−901	0	10
13	533	3	−898	66	5
14	595	64	−834	77	2
15	526	−6	−840	92	6
16	251	−281	−1,121	6	8
17	273	−259	−1,380	25	8
18	457	−75	−1,455	53	6
19	606	74	−1,381	93	5
20	183	−349	−1,730	0	10
Decade departure			−1,294		
21	355	−177	−1,907	37	8
22	432	−100	−2,007	61	7
23	627	95	−1,912	99	4
24	340	−192	−2,104	25	9
25	618	116	−1,988	79	3
26	343	−188	−2,176	14	9
27	757	226	−1,950	100	0
28	508	−23	−1,973	37	7
29	99	−431	−2,404	0	10
30	206	−324	−2,728	0	10
31	677	147	−2,581	90	3
Decade departure			−851		
Total deficiency since first of year			−1,672		

CONFIRMATORY EXPERIMENTS ON THE VALUE OF THE SOLAR CONSTANT OF RADIATION.[1]

By C. G. ABBOT, F. E. FOWLE, and L. B. ALDRICH.

[Presented to the National Academy of Sciences, Apr. 27, 1915.]

We have made hitherto nearly 1,000 determinations of the intensity of solar radiation outside the atmosphere at mean solar distance, termed the solar constant of radiation. The mean value found is 1.93 calories per square centimeter per minute. Langley's spectro-bolometric method was employed. This consists in determining the distribution of the energy in the solar spectrum at different solar zenith distances, and thereby computing coefficients of atmospheric transmission suitable to determine the energy curve outside the atmosphere. The bolometric measurements are reduced, in terms of standard 15° calories per square centimeter per minute, by the aid of comparisons made each day of observation with stand-

[1] For a description of instrumental exposures and methods of observation see this REVIEW, December, 1914, 42: 648.

[1] *Reprinted from* Proceedings, National Academy of Sciences, Washington, June 15, 1915, 1: 331–333.

ardized pyrheliometers. Observations have been made at Washington (sea level); Bassour, Algeria (1,160 meters); Mount Wilson, Cal. (1,730 meters); and Mount Whitney, Cal. (4,420 meters). They have continued during all the years 1903 to 1914. Great changes from day to day and from place to place in temperature, in barometric pressure, in humidity, in haziness, while of course greatly affecting measurements of intensity at the stations and of atmospheric transparency computed, nevertheless have not produced differences of the solar constant values. This seems to us to be strong evidence of the soundness of the method.

In the second place, it has been shown by Fowle that the atmospheric transmission coefficients obtained at Mount Wilson fit well with Lord Rayleigh's theory of atmospheric scattering, except for those regions of spectrum where numerous atmospheric lines and bands of true absorption are known to occur. Fowle has computed from the transmission coefficients that the number of molecules per cubic centimeter of air at standard temperature and pressure is $(2.70 \pm 0.02) \times 10^{19}$. This value is very close to Millikan's determination by absolutely independent observations and methods, namely $(2.705 \pm 0.005) \times 10^{19}$.

In the third place, simultaneous solar-constant observations at Mount Wilson and Bassour, separated by one-third the earth's circumference, unite in showing a substantial irregular variability of the sun from day to day. This solar variability has been of late independently confirmed by us by examination of the distribution of brightness along the diameter of the sun's disk. The latter observations show variations of distribution from day to day, and these accompany pretty closely the variations of the total solar radiation. It seems to us that, as the fact of solar variability is thus independently confirmed as a real phenomenon, it speaks favorably for the substantial accuracy of our solar-constant measurements that it was through them that the irregular variations of from 1 to 5 or, very rarely, 10 per cent were first discovered.

Notwithstanding these evidences of the soundness of our solar constant work, various attacks upon it have been made, tending to show that the solar constant is much higher than 1.93 calories, perhaps even 3.5 to 4.0 calories. A principal argument is that the atmospheric transparency continually diminishes as the sun rises within 75° zenith distance, so that our values of atmospheric transmission are much too great and have no relation to the transmission of an atmosphere of constant transparency. Secondly, it is said that measurements of solar radiation exceeding 1.93 calories have been made on mountain tops and from free balloons. Various other objections are raised, which we discuss in our paper now being published by the Smithsonian Institution.[2]

On two days, September 20 and 21, 1914, we continued solar-constant observations at Mount Wilson from the instant of sunrise until about 10 o'clock. We have reduced the work by the aid of Bemporad's air-mass formulæ and tables. As these postulated uniform optical quality of the atmosphere from bottom to top, it was necessary to apply certain corrections to them varying with the wave-length, depending upon the extinction by water vapor residing in the lowest atmospheric strata. We were enabled to determine these corrections by Fowle's studies of the effects of water vapor. We find on both days that the atmospheric transparency remained sensibly unaltered from sunrise to 10 o'clock. Closely identical values of the solar constant are obtained, whatever the range of air masses used to determine the atmospheric transmission. We made three independent estimates for each day, for air-mass ranges 1.3 to 4; 4 to 12; and 1.3 to 20, respectively. All six solar-constant values thus found fall between 1.90 and 1.95 calories. The smallest air masses, as it happens, yield slightly the highest values. We conclude that our previous results have not been made too small by neglecting to observe during the time when the sun is within 15° of the horizon.

On July 11, 1914, in cooperation with the United States Weather Bureau, a recording pyrheliometer attached to sounding balloons was sent up to the altitude of about 24 km., where the barometric pressure was 3 cm. of mercury, which is only one twenty-fifth of that prevailing at sea level.

Good records of solar radiation were obtained over a period of more than an hour and including the period when the instrument reached its highest elevation. The mean value of the best three records made at highest altitudes, as reduced to mean solar distance, comes out 1.84 calories per square centimeter per minute. We believe that about 2 per cent should be added to represent radiation scattered and absorbed in the atmosphere above the level reached, making the probable value of the solar constant, from this day's work, 1.88 calories. This value falls decidedly within the range of solar constant values we have observed. We state in connection with it the following results, which are the highest reliable direct observations of solar radiation at the various altitudes, as reduced to mean solar distance and vertical sun:

TABLE 1.—*The highest reliable direct observations of solar radiation at the various altitudes.*

[Reduced to mean solar distance and vertical sun.]

Station.	Washington.	Mount Wilson.	Mount Whitney.	Manned balloon.	Free balloon.
Altitude	127 m	1,730 m	4,420 m	7,500 m	24,000 m.
Barometer	75 cm	62 cm	45 cm	30 cm	3 cm.
Radiation	1.53 cal	1.64	1.72	1.755	1.84 cal.
Observer	Kimball	Abbot	Abbot	A. Peppler.	(Smithsonian.)

SOLAR HALO OF MAY 11, 1915, AT SAND KEY, FLA.

By CLARENCE G. ANDRUS, Assistant Observer.

[Dated: Weather Bureau, Sand Key, Fla., May 11, 1915.]

On the afternoon of May 11, 1915, there was observed at Sand Key, Fla. ($\varphi = 24°\ 27'$ N.; $\lambda = 81°\ 53'$ W.), a rather unusual display of prismatic arcs in the heavens. The phenomena were observed and noted with the strictest accuracy possible under the circumstances, but it is regretted that no instrumental measurements and no photographs of the halos could be secured. The somewhat crude observing methods practicable were carefully carried out and the author feels certain that errors were nearly eliminated. All records are in 90th meridian time. The observations were made by the writer, and Mr. H. L. Riley carefully checked and confirmed the data.

The cloud forms causing the phenomena were of the cirro-stratus type and were moving toward the east. Throughout the afternoon the sky was about 5/10 covered, the cirro-stratus being arranged as a broad band from east to west. The edge to the southward was well defined and appeared as an upwardly curling front on which no halo-form curves were seen. In structure the clouds were not of pallium form but were filamentary and might well be described as resembling the warp and woof threads in a threadbare cloth.

[2] **Abbott, C. G.,** *and others.* New evidence on the intensity of solar radiation outside the atmosphere. Washington, 1915. p. I., 55 p. 8°. (Smithsonian misc. coll., v. 65, no. 4. Publ. 2361.)